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# Heavy Metals Contamination of Topsoil and Dispersion in the Vicinities of Reclaimed Auto-Repair Workshops in Iwo, Nigeria

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**Abstract:** Growing concern about reclamation of auto-repair workshop areas for residential and agricultural purposes makes risk assessment of heavy metal contamination in auto-repair workshop soils in Iwo, Nigeria imperative. In addition, the study is aimed at ascertaining the dispersion of contaminated heavy metals, notably Zn, Ni, Cr, Hg and Pb within the soil profile. Significant levels of contamination were found in view of elevated levels of the metals above background concentrations in control sites. Lead was the most significant contaminants and the degree of contamination was highest for Pb followed by Hg. Average factors of accumulation within the soil profile metals were Zn-3.37, Ni- 3.38, Cr-6.22, Hg-14.5 and Pb-21.1. Average topsoil metal concentrations (0-10 cm) in auto-repair workshop areas were: Zn-0.90±0.5 mg $kg^{-1}$, Ni-11.5±3.3 mg $kg^{-1}$, Cr-5.3±2.3 mg $kg^{-1}$, Hg-9.4±4.6 mg $kg^{-1}$ and Pb-133±66 mg $kg^{-1}$. The detailed levels of total metal contamination for Pb and Hg exceed international thresholds for agricultural use. The general trend of dispersion of metal contaminants within the soil profile studied is Pb>> Ni> Hg> Cr>>Zn.

**Key words:** Auto-repair, lead, mercury, soil, heavy metals, dispersion

## INTRODUCTION

Heavy metals are deemed serious pollutants because of toxicity, persistence and non- degradability in the environment (Fang and Hang, 1999; Klavins *et al*., 2000; Tam and Wong, 2000; Yuan *et al*., 2004; Hakan, 2006). Heavy metals are defined as trace metals with densities greater than 5 g $cm^{-3}$ (Duffus, 1980). Heavy metals are natural constituents of rock and soils and enter the environment as a consequence of weathering and erosion. Many metals are biologically essential, but all have the potential to be toxic to biota above certain threshold concentrations (David and Johanna, 2000). Adverse effects of elevated concentrations of heavy meals to soil functions, soil microbial community composition and microbial growth have long been recognized under both field and laboratory conditions (Tyler *et al*., 1989; D'Ascol *et al*., 2005). Heavy metal contamination of urban topsoil usually derives from anthropogenic sources such as emissions from automobile exhaust, waste incineration, land disposal of wastes, use of agricultural inputs, emissions from industrial processes and wet and/or dry atmospheric deposits (Onianwa *et al*., 2001; Zhenli *et al*., 2005). A large body of literature is available concerning automobile exhaust emissions as the major non-point source of lead in roadside dusts. Other metals such as zinc, cadmium, copper, chromium, nickel, barium, aluminium and manganese are also associated with automobile-related pollution. These are often used as minor additives to gasoline and various auto-lubricants and are released during combustion and spillage (Loranger *et al*., 1994; Lytle *et al*., 1995). In 1990, Canada banned lead and added Methylcyclopentadienyl Manganese Tricarbonyl (MMT) to gasoline (Stevenson, 1991; Normandin *et al*., 1999). MMT is an organic derivative of manganese, which is added to gasoline as an antiknock agent and to improve octane rating (Hinderer, 1979). Some of these metals are components of automobile parts such as tyres and engines, from which they are released during abrasion and wears.

There has been little attention given to vicinities of automobile-workshops, which are also liable to pollution arising from gasoline combustion exhausts, lubricating oil spills and other chemical inputs to automobile operations. In Nigeria, pollution problems associated with incidents of oils spills around automobile-repair workshops, resulting in metal contamination of topsoil, have been the subject of many reports (Osibanjo *et al*., 1983; Oyido and Agboola, 1983; Onianwa *et al*., 2001). Auto repair workshops are facilities where automobiles are usually operated in semi- stationary or stationary

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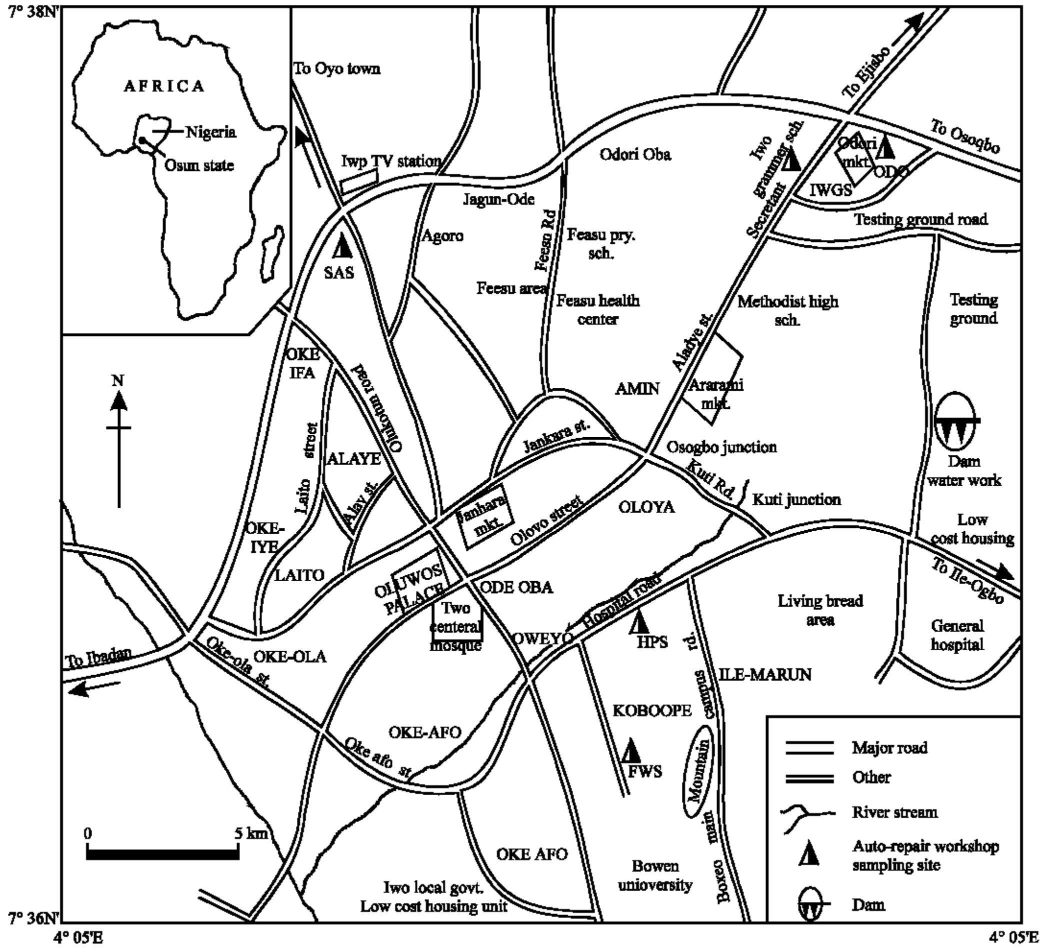


Fig. 1: Map of Iwo town showing sampling areas

modes. This tends to aggravate the direct deposition of exhaust emissions and scrap batteries and solder. Auto-repair workshops in Iwo town are of interest in this study because of reclamation of land upon which these workshops were situated for residential purposes owing to a dramatic rise in the population. The emergence of Bowen University in Iwo is enough a reason for the increasing population. Most residents exclude some portion at the backyard for vegetation. Possibility may arise to dig a well in residential houses erected on such reclaimed auto-repair workshop land. Soil, being a complex porous material, retains and transports hazardous pollutants to ground water (Pickett *et al.*, 2001; Liu *et al.*, 2006). This makes residents directly vulnerable to soil contaminants. Each of these workshops usually hosts a variety of artisans such as auto-electricians, battery servicemen, vulcanisers and panel beaters. Scrap batteries and solder, waste engine oil, brake fluid and other fluid generated by their activities in the workshop are not properly disposed off. They are usually thrown away on the soil. Heavy metals such as zinc, lead, cadmium, copper, manganese and nickel, which are often contained as additives in some of these lubricants and gasoline, are non-degradable in the soil. Chromium is classified as priority pollutants by United States Environmental Protection Agency (USEPA) with a carcinogenicity classification A (human carcinogen), while lead is classified in the same list with a carcinogenicity B (probable human carcinogen) (USEPA, 1999). Crops raised on the metal-contaminated soils accumulate metals in quantities excessive enough to cause clinical problems both to animals and human beings consuming those metal rich plants (Tiller, 1986; Rattan *et al.*, 2005). Thus, accumulation of heavy metals in the soil has potential to restrict the soil's function, causing toxicity to plants and contaminate the food chain. In recent years, it has been investigated that heavy metals from point and non-point sources impair water system including drinking wells, causing lesions (Henry *et al.*, 2004). Possibility exits for lateral migration of heavy metals towards drinking wells dug in these reclaimed auto-repair workshop areas. Filtration and settling of heavy metals via soil into such well exposes residents of such areas to unsafe water for drinking and domestic use. Exposure of residents of these areas to high concentrations of metals such as Pb can lead to numerous health problem, especially in neurological, respiratory and excretory (gastrointestinal absorption) systems (Partiarca *et al.*, 2000). Since, the activity of artisans in auto-repair workshops in Iwo is one of the major routes for entry of heavy metals into the environment to cause contamination of soil and drinking wells and crops, monitoring the available pools of metals in contaminated soils becomes relevant. There has not been any information in the scientific literature on soil quality, especially heavy metal distribution in auto-repair workshop soils of the study area. This investigation was carried in order to clarify the spatial distribution of heavy metals and extent of contamination in the vicinities of auto-repair workshops in Iwo town. Iwo is one of the largest town in Southwestern Nigeria. It lies on latitude 7°36′-7°40′S and longitude 4°5′-4°13′W and is about 300 m above the sea level. The underly geology of the area comprise of migmatite, augen gneiss, pegmatite and quartzite. Figure 1 is the map of Iwo town showing the sampling sites in the town. Therefore, the objectives were as follows

- To establish the spatial variability in concentrations of Zn, Ni, Cr, Hg and Pb for topsoils in some auto-repair workshops, where high levels of these metals were suspected on the basis of activities in the areas.
- To assess the level and extent of contamination by comparison with international soil standards and to identify any need for regular monitoring and/or remediation.
- To investigate the dispersion of the metal concentrations with increasing soil depth.

## MATERIALS AND METHODS

**Description of sampling sites:** Soil samples from five different auto-repair workshops were collected in Iwo town in September 2006. The sampling locations are traversed by major road. The location, sampling site code and feasible features around the auto-repair workshops are highlighted as follows:

- The first auto-repair workshop is located in front of Iwo Grammar School (IWGS). Residential houses surround it. Automobile exhaust, scrap batteries, paints and used engine oil was seen on the ground.
- The second auto-repair workshop is at Odori market (ODO), which is a major and most busy market for trade. Refuse dump site is not far from the sampling site. The site was littered with paint, scrap batteries and engine oil containers.
- The third auto-repair workshop is located in front of Saint Anthony Primary School (SAS). The site is surrounded with some vegetation. Automobile exhaust and used engine oil were noticed on the ground.
- The fourth site is at Hospital road (HPS), which is very close to the only general hospital in the town. The auto-repair workshop is not too far from residential houses. Some vegetation surrounds the site and few scrap metals and solders are indiscriminately disposed.
- The fifth mechanic workshop is along Fawibe Street (FWS). Similarly, the site is very close to residential houses on a side. On the other side of the site, some vegetation and a mountain mediated between the site and the fence of Bowen University Campus. The auto-repair was littered with scrap metals, automobile exhaust.
- Some control sites free from auto repair work shops and automobile exhaust were also considered.

**Sampling design:** Soil sampling survey was carried out between September 2006. The surrounding in each of the auto-repair workshop was divided into five radial transects to investigate the variation of heavy metal concentration at the site. The directions of those transects are as follows:

- North-west direction.
- South-west direction.
- North-east direction.
- South-east direction.
- West direction.

The total number of samples collected from the vicinity of each mechanic workshop was fifteen. Five samples were taken from the top 0-15 cm of the soil. The topsoil represented as T was scooped with the hand towel at a location along each transect. The ground at each location along each transect was dug with a digger to a depth of 20-30 and 35-40 cm, respectively. Depth samples (20-30 and 35-40 cm) were also taken at these locations to investigate the variation of the metal concentrations with increasing soil depth (objective 3).

## RESULTS

Heavy metals concentrations and characteristics of top and deep soil of the study sites are given in Table 1-4

Table 1: Heavy metal concentrations (mg kg$^{-1}$) and characteristics of Top (T) and Deep soil samples (D) from auto-repair Workshop at Iwo drammar School (IWGS)

| Sampling site code | Depth (cm) | pH | Moisture (%) | Sand (%) | Clay (%) | Silt (%) | TOC (%) | TOM (%) | Zn | Ni | Cr | Hg | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IWGS1 | T(0-10) | 7.2 | 3.4 | 32.4 | 4.0 | 64.6 | 3.17 | 5.47 | 1.65 | 16.5 | 13.4 | 14.3 | 298 |
| | D1(15-20) | 7.4 | 4.1 | 24.4 | 12.0 | 63.3 | 3.34 | 5.76 | 0.85 | 12.5 | 9.15 | 9.52 | 253 |
| | D2(25-30) | 6.7 | 8.4 | 9.6 | 12.0 | 78.4 | 3.80 | 6.56 | <0.01 | 6.20 | 6.20 | 7.72 | 237 |
| IWG2 | T(0-10) | 7.1 | 1.5 | 88.4 | 4.0 | 7.6 | 1.78 | 3.07 | 1.35 | 8.50 | 7.25 | 9.04 | 202 |
| | D1(15-20) | 6.5 | 2.7 | 88.4 | 4.0 | 7.6 | 2.40 | 4.14 | 1.05 | 6.85 | 4.10 | 5.60 | 136 |
| | D2(25-30) | 6.4 | 7.0 | 32.4 | 12.0 | 55.6 | 3.77 | 6.50 | 0.45 | 4.50 | 1.05 | 2.14 | 108 |
| IWGS3 | T(0-10) | 6.9 | 4.0 | 72.4 | 20.0 | 7.6 | 0.82 | 1.42 | 1.90 | 14.0 | 6.15 | 8.96 | 143 |
| | D1(15-20) | 6.6 | 6.2 | 72.4 | 20.0 | 7.6 | 0.88 | 1.52 | 1.25 | 10.5 | 2.60 | 3.76 | 104 |
| | D2(25-30) | 6.1 | 9.9 | 48.4 | 12.0 | 39.6 | 1.94 | 3.35 | 0.85 | 4.50 | 2.04 | 3.05 | 28.0 |
| IWGS4 | T(0-10) | 6.5 | 7.2 | 56.4 | 12.0 | 31.6 | 0.45 | 0.78 | 2.05 | 12.0 | 3.50 | 3.61 | 130 |
| | D1(15-20) | 6.7 | 7.0 | 80.4 | 12.0 | 7.6 | 1.50 | 2.60 | 1.55 | 10.0 | 2.15 | 1.52 | 74 |
| | D2(25-30) | 6.4 | 7.8 | 56.4 | 4.0 | 39.6 | 3.88 | 6.70 | 1.01 | 10.0 | 1.20 | <0.01 | 34.5 |
| IWGS5 | T(0-10) | 7.1 | 4.0 | 64.4 | 4.0 | 31.6 | 3.82 | 6.58 | 1.75 | 17.5 | 2.75 | 3.61 | 106 |
| | D1(15-20) | 6.7 | 6.5 | 64.4 | 4.0 | 31.6 | 3.88 | 6.70 | 0.90 | 12.5 | 2.20 | 2.05 | 62.4 |
| | D2(25-30) | 6.9 | 10.9 | 56.4 | 4.0 | 39.6 | 3.71 | 6.40 | 0.45 | 7.55 | 1.05 | 1.25 | 47.5 |
| | *T(0-10) | 7.0±0.3 | 4.0±2.1 | 63±21 | 8.8±7.2 | 29±23 | 2.0±1.5 | 3.5±2.5 | 1.74±0.27 | 13.7±3.6 | 6.6±4.2 | 7.9±4.5 | 175±77 |
| | *D1(15-20) | 6.8±0.4 | 5.3±1.8 | 66±25 | 10.4±6.7 | 24±25 | 2.4±1.2 | 4.1±2.1 | 1.03±0.41 | 9.5±2.3 | 9.5±2.3 | 4.3±3.4 | 123±80 |
| | *D2(25-30) | 6.5±0.3 | 8.8±1.6 | 41±20 | 8.8±4.4 | 51±17 | 3.42±0.83 | 5.9±1.4 | 0.69±0.28 | 6.6±2.3 | 6.6±2.3 | 3.5±2.9 | 91±88 |

Average value (*), Total Organic Carbon (TOC) and Total Organic Matter (TOM)

Table 2: Heavy metal concentrations (mg kg$^{-1}$) and characteristics of Top (T) and Deep soil samples (D) from auto-repair workshop at Odori (ODO)

| Sampling site code | Depth (cm) | pH | Moisture (%) | Sand (%) | Clay (%) | Silt (%) | TOC (%) | TOM (%) | Zn | Ni | Cr | Hg | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ODO1 | T(0-10) | 6.8 | 5.2 | 24.4 | 12.0 | 63.6 | 0.31 | 0.53 | 0.55 | 9.75 | 7.00 | 12.1 | 122 |
| | D1(15-20) | 7.2 | 8.0 | 40.4 | 4.0 | 55.6 | 0.72 | 1.24 | 0.25 | 8.50 | 5.25 | 7.50 | 107 |
| | D2(25-30) | 6.2 | 16.0 | 84.4 | 10.0 | 5.6 | 1.33 | 2.29 | 0.25 | 7.00 | 2.75 | 2.34 | 59 |
| ODO2 | T(0-10) | 6.4 | 1.4 | 84.4 | 10.0 | 5.6 | 0.31 | 0.53 | 0.75 | 10.5 | 7.50 | 5.50 | 217 |
| | D1(15-20) | 6.5 | 2.9 | 88.4 | 4.0 | 7.6 | 0.35 | 0.60 | 0.40 | 8.25 | 3.95 | 2.71 | 184 |
| | D2(25-30) | 6.8 | 1.5 | 24.4 | 12.0 | 63.6 | 0.63 | 1.09 | 0.35 | 7.50 | 3.50 | 1.34 | 126 |
| ODO3 | T(0-10) | 6.8 | 1.0 | 24.4 | 10.0 | 65.6 | 0.47 | 0.81 | 0.50 | 9.00 | 3.40 | 7.45 | 97.6 |
| | D1(15-20) | 6.4 | 2.7 | 72.4 | 12.0 | 15.6 | 0.62 | 1.06 | 0.30 | 8.00 | 2.55 | 4.78 | 30.2 |
| | D2(25-30) | 6.9 | 7.0 | 40.4 | 4.0 | 55.6 | 3.90 | 6.72 | 0.05 | 6.50 | 2.05 | 3.61 | <0.04 |
| ODO4 | T(0-10) | 6.2 | 4.1 | 84.4 | 10.0 | 5.6 | 0.67 | 1.16 | 0.40 | 8.50 | 3.75 | 4.65 | 191 |
| | D1(15-20) | 6.9 | 4.9 | 88.4 | 4.0 | 7.6 | 3.59 | 6.19 | 0.30 | 8.50 | 2.35 | 3.55 | 127 |
| | D2(25-30) | 6.8 | 6.7 | 88.4 | 4.0 | 7.6 | 3.74 | 6.44 | 0.15 | 7.55 | 2.05 | 2.40 | 87.3 |
| | *T(0-10) | 6.6±0.3 | 2.9±2.0 | 54±35 | 10.5±1.0 | 35±34 | 0.44±0.17 | 0.76±0.30 | 0.55±0.15 | 9.44±0.88 | 5.4±2.1 | 7.4±2.1 | 157±56 |
| | *D1(15-20) | 6.8±0.4 | 4.6±2.5 | 72±23 | 6.0±4.0 | 22±23 | 1.3±1.5 | 2.3±2.6 | 0.31±0.06 | 8.31±0.24 | 3.6±1.4 | 4.6±2.1 | 112±63 |
| | *D2(25-30) | 6.7±0.3 | 7.8±6.0 | 59±31 | 7.5±4.1 | 33±31 | 2.4±1.7 | 4.1±2.9 | 0.20±0.13 | 7.14±0.49 | 2.59±0.69 | 2.42±0.93 | 91±34 |

Average value (*), Total Organic Carbon (TOC) and Total Organic Matter (TOM)

Table 3: Heavy metal concentrations (mg kg$^{-1}$) and characteristics of Top (T) and Deep soil samples (D) from auto-repair workshop at Hospital road (HPS)

| Sampling site code | Depth (cm) | pH | Moisture (%) | Sand (%) | Clay (%) | Silt (%) | TOC (%) | TOM (%) | Zn | Ni | Cr | Hg | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HPS1 | T(0-10) | 6.5 | 5.6 | 8.4 | 12.0 | 23.6 | 1.04 | 1.79 | 0.25 | 10.5 | 5.20 | 8.74 | 125 |
| | D1(15-20) | 7.1 | 8.1 | 1.4 | 4.0 | 79.6 | 1.97 | 3.40 | 0.10 | 8.50 | 3.65 | 6.24 | 102 |
| | D2(25-30) | 6.6 | 9.1 | 56.4 | 4.0 | 39.6 | 3.80 | 6.59 | <0.05 | 7.05 | 3.25 | 3.38 | 62.1 |
| HPS2 | T(0-10) | 6.4 | 2.0 | 8.4 | 12.0 | 23.6 | 2.08 | 3.59 | 0.70 | 12.0 | 4.05 | 25.5 | 134 |
| | D1(15-20) | 6.9 | 4.2 | 8.4 | 12.0 | 79.6 | 3.32 | 5.70 | 0.40 | 8.00 | 3.95 | 15.0 | 81.3 |
| | D2(25-30) | 6.2 | 7.0 | 16.4 | 4.0 | 79.6 | 3.62 | 6.25 | 0.25 | 6.25 | 3.65 | 10.2 | 54.1 |
| HPS3 | T(0-10) | 6.4 | 4.2 | 56.4 | 12.0 | 31.6 | 0.08 | 0.14 | 1.85 | 15.5 | 6.05 | 8.74 | 172 |
| | D1(15-20) | 6.6 | 4.0 | 64.4 | 12.0 | 23.6 | 0.20 | 0.34 | 1.25 | 6.50 | 3.55 | 8.74 | 153 |
| | D2(25-30) | 6.7 | 9.8 | 64.4 | 12.0 | 23.6 | 0.36 | 0.62 | 1.10 | 5.50 | 3.15 | 6.10 | 120 |
| HPS4 | T(0-10) | 6.6 | 1.5 | 56.4 | 12.0 | 31.6 | 1.06 | 2.00 | 0.90 | 13.0 | 5.05 | 10.3 | 110 |
| | D1(15-20) | 6.2 | 5.2 | 56.4 | 12.0 | 31.6 | 3.26 | 5.63 | 0.65 | 11.5 | 3.80 | 7.24 | 105 |
| | D2(25-30) | 6.8 | 7.0 | 64.4 | 4.0 | 31.6 | 3.83 | 6.61 | 0.35 | 5.50 | 3.25 | 3.28 | 87.5 |
| HPS5 | T(0-10) | 6.1 | 1.7 | 80.4 | 4.0 | 15.6 | 2.08 | 3.59 | 0.85 | 9.25 | 4.60 | 9.89 | 120 |
| | D1(15-20) | 6.5 | 2.0 | 80.4 | 4.0 | 15.6 | 3.57 | 6.15 | 0.60 | 7.50 | 2.35 | 7.06 | 77.0 |
| | D2(25-30) | 6.5 | 7.2 | 40.4 | 4.0 | 55.6 | 3.87 | 6.68 | 0.50 | 4.50 | 2.05 | 5.74 | 58.1 |
| | *T(0-10) | 6.4±0.2 | 3.0±1.8 | 42±32 | 10.4±3.6 | 25.2±6.7 | 1.27±0.84 | 2.2±1.4 | 0.91±0.58 | 12.1±2.4 | 4.99±0.74 | 12.6±7.2 | 132±24 |
| | *D1(15-20) | 6.7±0.4 | 4.7±2.2 | 42±35 | 8.8±4.4 | 46±31 | 2.5±1.4 | 4.2±2.4 | 0.60±0.42 | 8.4±1.9 | 3.46±0.64 | 8.86±3.6 | 103±30 |
| | *D2(25-30) | 6.6±0.2 | 8.0±1.3 | 48±20 | 5.6±3.6 | 46±22 | 3.1±1.5 | 5.4±2.6 | 0.63±0.36 | 7.0±3.1 | 3.18±0.79 | 6.5±2.0 | 80±33 |

Average value (*), Total Organic Carbon (TOC) and Total Organic Matter (TOM)

Table 4: Heavy metal concentrations (mg $kg^{-1}$) and characteristics of Top (T) and Deep soil samples (D) from auto-repair workshop at St. Anthony primary School (SAS)

| Sampling site code | Depth (cm) | pH | Moisture (%) | Sand (%) | Clay (%) | Silt (%) | TOC (%) | TOM (%) | Zn | Ni | Cr | Hg | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAS1 | T(0-10) | 6.4 | 1.8 | 16.4 | 4.0 | 79.6 | 3.25 | 5.60 | 0.65 | 17.2 | 6.20 | 11.7 | 168 |
| | D1(15-20) | 6.8 | 1.5 | 32.4 | 13.0 | 54.6 | 3.67 | 6.33 | 0.40 | 15.5 | 5.50 | 8.50 | 121 |
| | D2(25-30) | 6.8 | 5.4 | 40.4 | 4.0 | 55.6 | 3.74 | 6.46 | 0.15 | 9.50 | 3.10 | 4.02 | 101 |
| SAS2 | T(0-10) | 6.3 | 2.0 | 16.4 | 4.0 | 79.6 | 1.95 | 3.36 | 0.70 | 9.00 | 4.05 | 6.85 | 130 |
| | D1(15-20) | 6.6 | 2.9 | 16.4 | 4.0 | 79.6 | 2.29 | 3.65 | 0.45 | 7.15 | 2.95 | 3.93 | 83.2 |
| | D2(25-30) | 6.9 | 9.0 | 88.4 | 4.0 | 7.6 | 3.05 | 5.27 | 0.30 | 6.05 | 1.50 | 3.26 | 65.5 |
| SAS3 | T(0-10) | 6.5 | 0.5 | 16.4 | 13.0 | 70.6 | 1.41 | 2.43 | 0.55 | 14.0 | 6.58 | 10.3 | 91.9 |
| | D1(15-20) | 6.5 | 0.5 | 8.4 | 12.0 | 79.6 | 2.30 | 3.98 | 0.45 | 12.5 | 3.50 | 7.40 | 70.1 |
| | D2(25-30) | 6.6 | 1.5 | 48.4 | 4.0 | 47.6 | 3.89 | 6.70 | 0.20 | 7.51 | 2.70 | 5.25 | 50.2 |
| SAS4 | T(0-10) | 6.6 | 1.8 | 88.4 | 4.0 | 7.6 | 3.04 | 5.24 | 0.60 | 9.50 | 3.55 | 7.20 | 12.0 |
| | D1(15-20) | 6.4 | 3.0 | 88.4 | 4.0 | 7.6 | 3.65 | 6.29 | 0.35 | 7.00 | 3.55 | 4.17 | 5.25 |
| | D2(25-30) | 6.6 | 5.0 | 86.4 | 12.0 | 1.6 | 3.83 | 6.60 | 0.15 | 5.25 | 2.05 | 3.05 | <0.04 |
| SAS5 | T(0-10) | 7.2 | 3.9 | 88.4 | 4.0 | 7.6 | 3.08 | 5.31 | 0.85 | 17.5 | 8.10 | 15.2 | 119 |
| | D1(15-20) | 6.8 | 5.2 | 60.4 | 24.0 | 15.6 | 3.51 | 6.05 | 0.60 | 15.0 | 7.20 | 9.52 | 96.5 |
| | D2(25-30) | 6.7 | 15.0 | 32.4 | 4.0 | 63.6 | 3.90 | 6.73 | 0.50 | 11.5 | 5.50 | 7.20 | 70.1 |
| | *T(0-10) | 6.6±0.4 | 2.0±1.2 | 45±39 | 5.8±4.0 | 49±38 | 2.54±0.82 | 4.4±1.4 | 0.67±0.12 | 13.4±4.1 | 5.8±1.9 | 10.3±3.4 | 104±58 |
| | *D1(15-20) | 6.6±0.2 | 2.6±1.8 | 41±33 | 11.0±8.3 | 47±34 | 3.1±0.7 | 5.3±1.3 | 0.45±0.09 | 11.4±4.1 | 4.54±1.8 | 6.70±2.5 | 75±43 |
| | *D2(25-30) | 6.7±0.1 | 7.2±5.1 | 59±26 | 5.6±3.6 | 35±29 | 3.68±0.36 | 6.35±0.61 | 0.26±0.15 | 8.0±2.6 | 3.0±1.5 | 4.6±1.7 | 72±21 |

Average value (*), Total Organic Carbon (TOC) and Total Organic Matter (TOM)

**The composition of soil and heavy metal levels in auto-repair workshop at Iwo Grammar Schol (IWGS):** The soil pH varied from 6.1-7.4 on the average. Soil pH of the top soil (7.0±0.3) dropped with depths by 0.5 unit as soil depth increased up to 30 cm (Table 1). The total organic carbon varied from 0.45-3.82% in the top soil T(0-10 cm) and 1.94-3.88% in the deep soil D2(25-30 cm). The average composition of total organic carbon increased from 2.0±1.5% in the top soil to 3.42±0.83% in deep soil D2(25-30 cm). The total organic matter showed average values ranging from 3.5±2.5% in the top soil T(0-10 cm) to 5.9±1.4% in the deep soil D2(25-30 cm) (Table 1). The percentage moisture value varied from 1.5-7.2% in the deep soil T (0-10 cm) and 7.0-10.9% in the deep soil D2 (Table 1). On the average, moisture contents of 4.0±2.1%, 5.3±1.8% and 8.8±1.6% were obtained in the top soil T, deep soil D1 and D2, respectively. The mechanical analysis of soil samples indicated that sand and silt contents, on an average, ranged from 41±20-3±21% and 24±25-51±17%, respectively. The lead level varies from 106-298 mg $kg^{-1}$ in the topsoil and 28.0-237 mg $kg^{-1}$ at 25-30 cm depth. Table 1 revealed that lead has the highest average concentration in the topsoil followed by nickel, mercury, chromium and zinc respectively. The average concentrations of Zn, Ni Cr, Hg and Pb decreased markedly with depths up to 30 cm (Table 1 and Fig 2-6).

**The composition of soil and heavy metal levels in auto-repair workshop at Odo- Ori (ODO):** Table 2 shows that soil pH ranges from 6.2-6.8 in the top soil T and 6.2-6.9 in the deep soil D2. The average total organic carbon of 0.44±0.17% in the top soil increased with depths to 2.4±1.7%. The total organic matter showed a value ranging from 0.53-1.16% in the top soil T and 1.09-6.72% in the deep soil D2. The average moisture content of the soil increased with depths, ranging from 2.9±2.0% in the top soil T (0-10 cm) to 7.8±6.0 in the deep soil

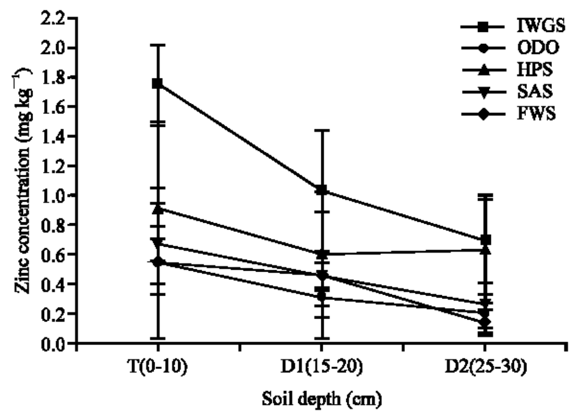


Fig. 2: Overall variation of zinc levels with soil depth at sampling locations

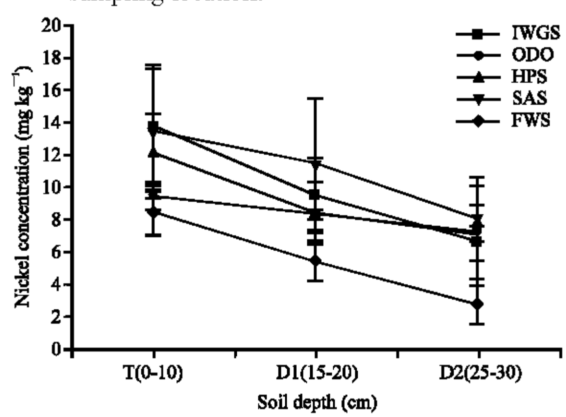


Fig. 3: Overall variation of nickel levels with soil depth at sampling locations

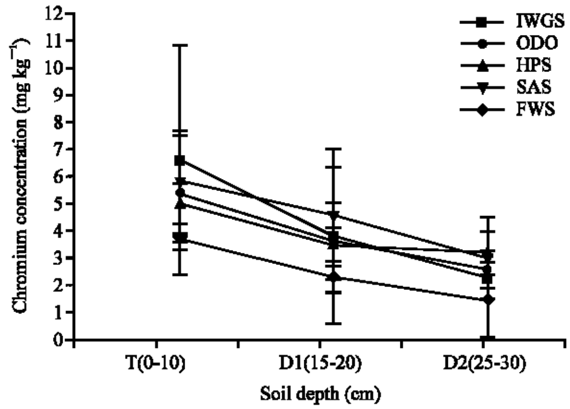


Fig. 4: Overall variation of chromium levels with soil depth at sampling locations

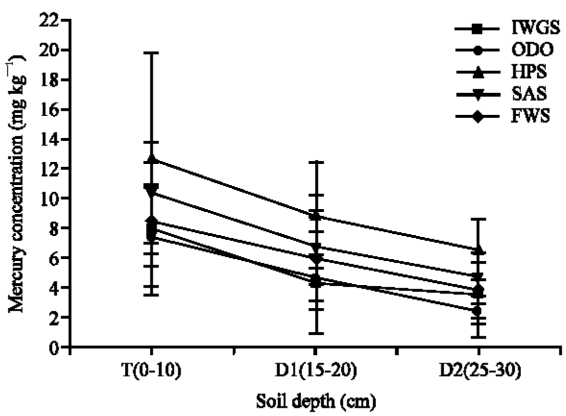


Fig. 5: Overall variation of mercury levels with soil depth at sampling locations

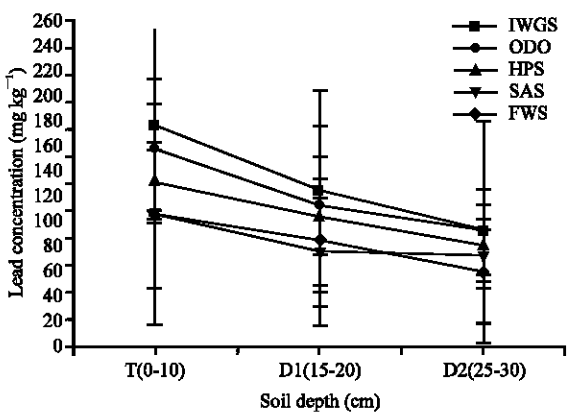


Fig. 6: Overall variations of lead levels with soil depth at sampling locations

D2 (25-30 cm). On an average, the top soil samples consisted of 10.5±1.0% of clay, 54±35% of sand and 35±34% of clay. The corresponding compositions in the deep soil D2 (25-30 cm) are 7.5±4.1, 59±31 and 33±31%, respectively (Table 2). Average meal concentrations of Zn, Ni Cr, Hg and Pb were 0.55±0.15, 9.44±0.88, 5.4±2.1, 7.4±2.1 and 157±56 mg $kg^{-1}$, respectively. To investigate the vertical extent of soil contamination, corresponding metal concentrations at 25-30 cm depth were 0.20±0.13, 7.14±0.49, 2.59±0.69, 2.42±0.93 and 91±34 mg $kg^{-1}$, respectively (Table 2). The metal levels were significantly reduced with soil depths (Table 2). The disperse patterns of the metals with depths is shown in Fig. 2-6. Relative abundance patterns of the metals in the topsoil and deep soil D1 (15-20 cm) were in the order Pb >> Ni > Hg > Cr >> Zn.

**The composition of soil and heavy meal levels in auto-repair workshop at Hospital road (HPS):** The pH ranged from 6.1-6.6 in the top soil T(0-10 cm) and 6.2-6.8 at 25-30 cm depth. The average moisture composition varied from 3.0±1.8% at 0-10 cm depth to 8.0±1.3% at 25-30 cm depth (Table 3). On an average, organic carbon content in the top soil was 1.27±0.84%. This level increased with depth up to 30 cm. Soil particles were mostly sand at the top and depth up to 30 cm. The grain size distribution of soil at the top revealed about 42±32% of sand, 10.4±3.6% of clay and 25.2±6.7% of silt. Lead has the highest concentrations ranging from 110-172 mg $kg^{-1}$ in the top soil and 58.1-120 mg $kg^{-1}$ in the deep soil D2 (25-30 cm). The average concentrations of Pb and other metals (Zn, Ni, Cr, Hg, Pb) decreased with depth. However, a slight rize in average zinc concentration of 0.60±0.42 mg $kg^{-1}$ at 15-20 cm depth to 0.63±0.36 mg $kg^{-1}$ at 25-30 cm depth (Table 3 and Fig. 2-6).

**The composition of soil and heavy metal levels in auto-repair workshops at St. Anthony (SAS):** The pH of the topsoil samples ranged from 6.3-7.2. The average pH values in the topsoil and deep soil were about the same values (Table 4). The percentage moisture composition varied from 0.5-3.9% at 0-10 cm depth and 1.5-15.0% at 25-30 cm depth. The moisture content increased with depth up to 30 cm depth (Table 4). The topsoil consisted of 45±39% of sand, 5.8±4.0% of clay and 49±38% of silt. The proportion of distribution of particle sizes in deep soil D2 (15-20 cm) followed similar order sit > sand >> clay as in the topsoil. T (0-10 cm). The total organic carbon levels varied from 1.41-3.25% at 0-10 cm depth and 3.05-3.90% at 25-30 cm depth. On an average, total organic carbon and total organic matter levels increased with depth up to 30 cm. Lead was quite high in concentrations at 0-10 cm depth. The average lead concentration at this

Table 5: Heavy metal concentrations (mg $kg^{-1}$) and characteristics of Top (T) and Deep soil samples (D) from auto-repair workshop along Fawibe Street (FWS)

| Sampling site code | Depth (cm) | pH | Moisture (%) | Sand (%) | Clay (%) | Silt (%) | TOC (%) | TOM (%) | Zn | Ni | Cr | Hg | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FWS1 | T(0-10) | 5.2 | 4.7 | 40.4 | 4.0 | 55.6 | 3.72 | 6.41 | 0.50 | 8.74 | 3.80 | 7.25 | 77.2 |
| | D1(15-20) | 5.7 | 4.0 | 56.4 | 4.0 | 39.6 | 3.45 | 5.95 | 0.25 | 5.20 | 2.35 | 5.44 | 52.1 |
| | D2(25-30) | 5.9 | 2.8 | 88.4 | 4.0 | 7.1 | 2.51 | 4.33 | 0.15 | 2.50 | 0.85 | 2.26 | 32.5 |
| FWS2 | T(0-10) | 5.7 | 2.4 | 40.4 | 4.0 | 55.6 | 1.04 | 1.79 | 0.30 | 8.05 | 3.50 | 6.41 | 18.7 |
| | D1(15-20) | 6.3 | 4.0 | 40.4 | 4.0 | 55.6 | 1.30 | 2.25 | 0.25 | 4.01 | 2.25 | 3.41 | 14.9 |
| | D2(25-30) | 5.9 | 7.9 | 72.4 | 12.0 | 15.6 | 3.75 | 6.46 | 0.25 | 2.50 | 1.55 | 2.26 | 9.25 |
| FWS3 | T(0-10) | 5.8 | 2.4 | 56.4 | 12.0 | 31.6 | 2.52 | 4.34 | 0.35 | 6.50 | 3.75 | 7.06 | 79.2 |
| | D1(15-20) | 6.4 | 2.8 | 80.4 | 12.0 | 7.6 | 3.46 | 5.97 | 0.25 | 5.50 | 1.80 | 3.41 | 70.1 |
| | D2(25-30) | 5.5 | 4.0 | 72.4 | 12.0 | 15.6 | 3.92 | 6.75 | 0.10 | 3.50 | 1.10 | 3.04 | 62.3 |
| FWS4 | T(0-10) | 6.2 | 8.4 | 40.4 | 12.0 | 47.6 | 3.10 | 5.34 | 0.05 | 10.5 | 3.75 | 9.74 | 254 |
| | D1(15-20) | 6.6 | 12.0 | 40.4 | 12.0 | 47.6 | 3.82 | 6.58 | <0.01 | 7.25 | 1.90 | 7.63 | 193 |
| | D2(25-30) | 6.4 | 22.0 | 40.4 | 12.0 | 47.6 | 3.88 | 6.69 | <0.01 | 4.05 | 1.15 | 6.26 | 115 |
| FWS5 | T(0-10) | 5.9 | 4.0 | 40.4 | 12.0 | 47.6 | 2.52 | 4.34 | 1.42 | 8.05 | 3.75 | 11.8 | 95.8 |
| | D1(15-20) | 6.2 | 8.2 | 24.4 | 12.0 | 63.6 | 3.71 | 6.40 | 1.10 | 5.05 | 3.20 | 9.74 | 90.5 |
| | D2(25-30) | 5.4 | 17.8 | 64.4 | 4.0 | 31.6 | 3.70 | 6.38 | 0.15 | 0.95 | 2.50 | 5.40 | 79.2 |
| | *T(0-10) | 5.8±0.4 | 4.4±2.5 | 43.6±7.1 | 8.8±4.4 | 47.6±9.8 | 2.58±0.99 | 4.4±1.7 | 0.54±0.51 | 8.4±1.4 | 3.71±0.12 | 8.5±2.3 | 105±88 |
| | *D1(15-20) | 6.2±0.3 | 6.2±3.8 | 48±21 | 8.3±4.4 | 43±22 | 3.1±1.0 | 5.4±1.8 | 0.46±0.43 | 5.4±1.2 | 2.3±0.55 | 5.9±2.8 | 84±67 |
| | *D2(25-30) | 5.8±0.4 | 10.9±8.6 | 68±18 | 8.8±4.4 | 24±16 | 3.6±0.6 | 6.1±1.0 | 0.14±0.09 | 2.7±1.2 | 1.43±0.35 | 3.8±1.9 | 60±41 |

Average value (*), Total Organic Carbon (TOC) and Total Organic Matter (TOM)

depth was 104±58 mg $kg^{-1}$. It decreased with depth to reflect concentration of 72±21 mg $kg^{-1}$ at 25-30 cm depth. The distribution patterns of other metals (Zn, Ni, Cr and Hg) were similar to that of Pb (Table 4 and Fig. 2-6). The relative abundance of the metals in both topsoil and deepsoil was Pb >> Ni > Hg >> Cr >> Zn.

**The composition of soil and heavy metal levels in auto-repair workshop along Fawibe Street (FWS):** The average pH values of the top soil and deep soil at 0-10, 15-20 and 25-30 cm were 5.8±0.4, 6.2±0.3 and 5.8±0.4, respectively (Table 5). The average percentage moisture increased with depth from 4.4±2.5% at 0-10 cm depth to 10.9±8.6 at 25-30 cm depth. The size distribution of particles in soil revealed 43.6±7.1% of sand, 83.0±4.4% of clay and 68±18% of sand as the dominant minerals at 0-10, 15-20 and 25-30 cm depths, respectively. The average total organic carbon level of the soil increased with depth from 2.58±0.99% at 0-10 to 3.6±0.6% at 25-30 cm (Table 5). Table 5 shows that lead has the highest average concentration of 105±88 mg $kg^{-1}$ in topsoil. However, this level decreased with depth such that lead concentration of 60±41 mg $kg^{-1}$ was obtained at 25-30 cm depth. The relative abundance of the metals in both topsoil and deepsoil up to 25-30 cm was Pb >> Hg > Ni > Cr > Zn (Table 5 and Fig. 2-6).

## DISCUSSION

Soils from the auto-repair workshops in Iwo town are coarse to moderately coarse in texture. This is deduced from high percentage sand and silt contents of the soil traceable to the geological formation of the area. The basement rocks underlying Iwo town are notably migmitite, quartizite, augen gneiss, charnockite and pegmatite. The auto-repair workshop soils, with neutral pH values, have more organic carbon. Soil organic matter within the organic surface layer is an important factor influencing metal concentration in the surface soils. Mechanisms for the release of metals from the surface layer include: Mineral chemical weathering via acid attack (Osterhelm and Astrom, 2002). Direct oxidation of the sulfides present, releasing bound metals and reductive dissolution of iron minerals due to flooding which releases trace metals that were associated with the iron oxides possibly present.

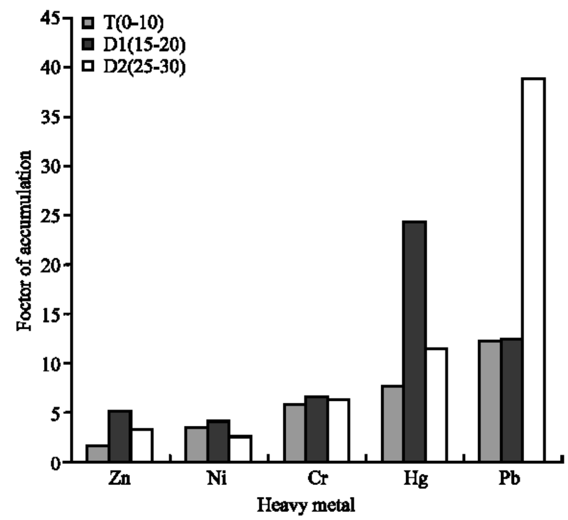

Fig. 7: Average factor of accumulation of heavy metals within the soil profile of auto repair workshop

Heavy metals in auto-repair workshop soils are not significantly derived from the natural geology of the area as are evident from the low level of metals in control samples (Table 6). Average levels of all the metals in auto-repair workshop soils were generally higher than prevailing background levels in control sites (Fig. 7).

Table 6: Comparison of average heavy metal concentrations (mg $kg^{-1}$) and characteristics of soil samples from auto-repair workshops with control in Iwo town

| Sampling site code | Depth (cm) | pH | Moisture (%) | Sand (%) | Clay (%) | Silt (%) | TOC (%) | TOM (%) | Zn | Ni | Cr | Hg | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IWGS | T(0-10) | 7.0±0.3 | 4.0±2.1 | 63±21 | 8.8±7.2 | 29±23 | 2.0±1.5 | 3.5±2.5 | 1.74±0.27 | 13.7±3.6 | 6.6±4.2 | 7.9±4.5 | 175±77 |
| (This study) | D1(15-20) | 6.8±0.4 | 5.3±1.8 | 66±25 | 10.4±6.7 | 24±25 | 2.4±1.2 | 4.1±2.1 | 1.03±0.41 | 9.5±2.3 | 9.5±2.3 | 4.3±3.4 | 123±80 |
| | D2(25-30) | 6.5±0.3 | 8.8±1.6 | 41±20 | 8.8±4.4 | 51±17 | 3.42±0.83 | 5.9±1.4 | 0.69±0.28 | 6.6±2.3 | 6.6±2.3 | 3.5±2.9 | 91±88 |
| ODO | T(0-10) | 6.6±0.3 | 2.9±2.0 | 54±35 | 10.5±1.0 | 35±34 | 0.44±0.17 | 0.76±0.30 | 0.55±0.15 | 9.44±0.88 | 5.4±2.1 | 7.4±2.1 | 157±56 |
| (This study) | D1(15-20) | 6.8±0.4 | 4.6±2.5 | 72±23 | 6.0±4.0 | 22±23 | 1.3±1.5 | 2.3±2.6 | 0.31±0.06 | 8.31±0.24 | 3.6±1.4 | 4.6±2.1 | 112±63 |
| | D2(25-30) | 6.7±0.3 | 7.8±6.0 | 59±31 | 7.5±4.1 | 33±31 | 2.4±1.7 | 4.1±2.9 | 0.20±0.13 | 7.14±0.49 | 2.59±0.69 | 2.42±0.93 | 91±34 |
| HPS | T(0-10) | 6.4±0.2 | 3.0±1.8 | 42±32 | 10.4±3.6 | 25.2±6.7 | 1.27±0.84 | 2.2±1.4 | 0.91±0.58 | 12.1±2.4 | 4.99±0.74 | 12.6±7.2 | 132±24 |
| (This study) | D1(15-20) | 6.7±0.4 | 4.7±2.2 | 42±35 | 8.8±4.4 | 46±31 | 2.5±1.4 | 4.2±2.4 | 0.60±0.42 | 8.4±1.9 | 3.46±0.64 | 8.86±3.6 | 103±30 |
| | D2(25-30) | 6.6±0.2 | 8.0±1.3 | 48±20 | 5.6±3.6 | 46±22 | 3.1±1.5 | 5.4±2.6 | 0.63±0.36 | 7.0±3.1 | 3.18±0.79 | 6.5±2.0 | 80±33 |
| SAS | T(0-10) | 6.6±0.4 | 2.0±1.2 | 45±39 | 5.8±4.0 | 49±38 | 2.54±0.82 | 4.4±1.4 | 0.67±0.12 | 13.4±4.1 | 5.8±1.9 | 10.3±3.4 | 104±58 |
| (This study) | D1(15-20) | 6.6±0.2 | 2.6±1.8 | 41±33 | 11.0±8.3 | 47±34 | 3.1±0.7 | 5.3±1.3 | 0.45±0.09 | 11.4±4.1 | 4.54±1.8 | 6.70±2.5 | 75±43 |
| | D2(25-30) | 6.7±0.1 | 7.2±5.1 | 59±26 | 5.6±3.6 | 35±29 | 3.68±0.36 | 6.35±0.61 | 0.26±0.15 | 8.0±2.6 | 3.0±1.5 | 4.6±1.7 | 72±21 |
| FWS | T(0-10) | 5.8±0.4 | 4.4±2.5 | 43.6±7.1 | 8.8±4.4 | 47.6±9.8 | 2.58±0.99 | 4.4±1.7 | 0.54±0.51 | 8.4±1.4 | 3.71±0.12 | 8.5±2.3 | 105±88 |
| (This study) | D1(15-20) | 6.2±0.3 | 6.2±3.8 | 48±21 | 8.3±4.4 | 43±22 | 3.1±1.0 | 5.4±1.8 | 0.46±0.43 | 5.4±1.2 | 2.3±0.55 | 5.9±2.8 | 84±67 |
| | D2(25-30) | 5.8±0.4 | 10.9±8.6 | 68±18 | 8.8±4.4 | 24±16 | 3.6±0.6 | 6.1±1.0 | 0.14±0.09 | 2.7±1.2 | 1.43±0.35 | 3.8±1.9 | 60±41 |
| Bowen | T(0-10) | 6.4±0.1 | 6.2±1.5 | 54±10 | 6.0±2.6 | 40.0±17 | 3.87±0.45 | 6.67±0.52 | 0.08±0.01 | 6.24±0.25 | 0.76±0.35 | 1.52±0.64 | 8.24±0.25 |
| (Control 1) | D1(15-20) | 6.1±0.1 | 7.4±1.3 | 42±18 | 8.8±3.9 | 49.2±0.8 | 4.52±0.36 | 7.79±0.30 | 0.06±0.05 | 4.11±0.14 | 0.52±0.07 | 0.25±0.08 | 10.4±1.3 |
| | D2(25-30) | 6.4±0.2 | 13.6±2.5 | 60±13 | 5.6±1.2 | 34.4±4.7 | 4.31±0.40 | 7.43±0.31 | <0.05 | 4.90±0.25 | 0.05±0.15 | 0.56±0.05 | <0.04 |
| Water works | T(0-10) | 7.2±0.5 | 8.7±1.5 | 42±18 | 7.5±2.8 | 50.5±1.2 | 3.28±0.27 | 5.65±0.56 | 0.21±0.03 | 0.17±0.11 | 1.05±0.08 | 0.89±0.05 | 15.0±2.1 |
| (Control 2) | D1(15-20) | 7.6±0.4 | 11.2±5.1 | 59±21 | 5.8±1.5 | 35.2±1.5 | 4.28±0.51 | 7.38±0.31 | 0.15±0.02 | 0.13±0.08 | 0.56±0.05 | 0.25±0.05 | 5.74±0.34 |
| | D2(25-30) | 7.4±0.5 | 12.9±4.2 | 54±13 | 5.8±1.0 | 40.2±5.6 | 5.62±0.32 | 9.69±0.50 | 0.12±0.02 | 0,10±0.04 | 0.74±0.03 | 0.10±0.07 | 2.04±0.15 |

Table 7: Comparison of metal levels (mg $kg^{-1}$) in this study with levels obtained from other cities and soil criteria for some countries

| | Zn | Ni | Cr | Hg | Pb |
|---|---|---|---|---|---|
| Iwo town,Nigeria (This study) | 0.90±0.57 | 11.5±3.3 | 5.3±2.3 | 9.4±4.6 | 133±66 |
| +Ibadan city, Nigeria | 48±37 | 10.5±9.7 | 22.1±9.6 | - | 81±140 |
| *Netherlands (action levels) | 720 | 210 | 380 | - | 530 |
| *Chinese soil | <3-790 | 35 | <100 | 0.04 | 13-42 |
| **CCME(Agricultural use) | 200 | 50 | 64 | 6.6 | 70 |
| **CCME (Residential use) | 200 | 50 | 64 | 6.6 | 140 |
| ** CCME (Commercial use) | 360 | 50 | 87 | 24 | 260 |
| ** CCME (Industrial use) | 360 | 50 | 87 | 50 | 600 |

+Onianwa *et al*., 2001, *Zhenli *et al*., 2005, ** Canadian Council of Ministers of the Environmental (CCME), 1999

This indicates significant level of pollution of reclaimed auto-repair workshop soils with Zn, Ni, Cr and Hg. The high concentration of Pb obtained in this study compared well to other metal concentrations from other city (Table 7) and is indicative of Pb being one of the major pollutant in the auto-workshop soils. The comparatively high Pb levels in auto-repair workshop soils may be due to fall-out of lead from batteries or lead accumulators, which are commonly used and abandoned in the workshops. The proximity of the workshop areas to a major road would have contributed to the Pb level accumulated in the soils. This is because lead is derived mostly from exhausts of vehicles, which in Nigeria is still used as minor additives to gasoline and various auto-lubricants. It is estimated that about 2800 metric tones of vehicular gaseous lead emission is deposited to urban areas in Nigeria annually.

Metals in soils of the auto-repair workshop are not all retained within the profile depth of 0-15 cm (Fig. 2-6). Average concentrations of Zn, Ni, Cr, Hg and Pb obtained from this study generally decreased vertically with soil depth. This illustrates the mobility potential of heavy metals down the soil profile. The reduction in metal concentrations with soil depth indicates the presence of bioavailable phases of the metals (exchangeable, carbonate-bound, reducible and oxidizable). Changes in soil electrode potentials and soil redox reactions will influence the release and retention of elements in all these phases (Chuan *et al*., 1996; Charlatchka and Cambier, 2000). These soil chemical properties may be attributed to the readily percolation, mobilization and dispersion of elements in all these phases down the soil profile. The general trend in the dispersion pattern of metals in the soils of auto-repair workshops is Pb>> Ni> Hg> Cr>> Zn.

The degree of contamination of soils of auto-repair workshops in Iwo town with Pb and Hg were higher than were observed for Zn, Ni and Cr (Table 8). Pb were a major contaminant at all sites with a mean accumulation factor of 21.2. Improper disposal of waste lubricants and auto-exhaust emission are likely source of high Pb contamination. This indicates the need for further investigation and an assessment of the suitability of the auto-workshop lands for agricultural use. Inter-element correlations for all sampling sites are shown in Table 9. There were significant correlation ($p<0.01$) for all pairs of Hg/Cr, Ni/Cr, Ni/Hg, Pb/Cr, Pb/Hg, Pb/Ni, Zn/Cr, Zn/Ni and Zn/Pb. This implies that these metals in the soils of auto-repair workshops are all contributes from automobile

Table 8: Factors of accumulation of heavy metals in top and deep soil

| Sampling site code | Depth (cm) | Zn | Ni | Cr | Hg | Pb |
|---|---|---|---|---|---|---|
| IWGS | T(0-10) | 3.3 | 4.3 | 7.3 | 6.5 | 15.1 |
| | D1(15-20) | 9.4 | 4.5 | 7.0 | 17.2 | 15.2 |
| | D2(25-30) | 5.8 | 2.6 | 5.8 | 10.6 | 44.6 |
| ODO | T(0-10) | 1.0 | 2.9 | 5.9 | 6.1 | 13.5 |
| | D1(15-20) | 2.8 | 3.9 | 6.7 | 18.4 | 13.9 |
| | D2(25-30) | 1.7 | 2.9 | 6.5 | 1.36 | 45.5 |
| HPS | T(0-10) | 1.7 | 3.8 | 5.5 | 10.4 | 14.4 |
| | D1(15-20) | 5.5 | 4.0 | 6.3 | 35.4 | 12.8 |
| | D2(25-30) | 5.3 | 2.8 | 8.0 | 19.7 | 39.2 |
| SAS | T(0-10) | 1.3 | 4.2 | 6.4 | 8.5 | 9.0 |
| | D1(15-20) | 4.1 | 5.4 | 8.4 | 26.8 | 9.3 |
| | D2(25-30) | 2.2 | 3.2 | 7.5 | 13.9 | 35.3 |
| FWS | T(0-10) | 1.0 | 2.6 | 4.1 | 7.0 | 9.1 |
| | D1(15-20) | 4.2 | 2.5 | 4.3 | 23.6 | 10.4 |
| | D2(25-30) | 1.2 | 1.1 | 3.6 | 11.5 | 29.4 |

* Ratio of average concentration at given location to concentration at control site

Table 9: Pearson correlation coefficients for inter-element associations

| | Cr | Hg | Ni | Pb | Zn |
|---|---|---|---|---|---|
| Hg | 0.656* | | | | |
| Ni | 0.593* | 0.409* | | | |
| Pb | 0.736* | 0.474* | 0.414* | | |
| Zn | 0.331* | 0.135 | 0.562* | 0.290* | |
| TOC | 0.233 | 0.099 | 0.160 | 0.234 | 0.362 |

* Statistically significant at $p<0.01$

sources such as lubricants and auto-exhaust emission. Average concentrations in topsoils obtained from this study are evaluated for their risk significance by comparison with some quality guidelines specified for the protection of human health. Since no soil quality guideline is available for Nigeria, those of Canada and the Netherlands were used for assessment (Table 8). The levels of Pb and Hg in topsoils from this study exceed the Canadian 7.0 and 6.6 mg $kg^{-1}$ guides, respectively for agricultural use. Given that locations of the auto-repair workshops are easily accessible for plant or crop production, it is significant that a number of the sampling points have Pb and Hg levels which exceed the Canadian limits for agricultural use. The overall level of contamination of auto-workshop soils in Iwo with Pb and Hg cannot thus produce foods that are adequate for animals or human beings in terms of health and nutrition, particularly in view of increasing degree of contamination within soil profile. Therefore, close monitoring and some remedial actions such as remediation of auto-workshop soils contaminated mostly with Pb and Hg are required. Average levels of Zn, Ni and Cr in topsoils of auto-repair workshops at all locations are generally lower than the respective soil guidelines for these metals.

## CONCLUSION

In conclusion, soils in the vicinities of reclaimed auto-repair workshops were noted to be significantly contaminated with Pb and Hg. The disposal of waste lubricant oil and auto-exhaust emission are suspected to be a significant source of meal contamination of topsoil in these workshops. Metals concentrations were generally found to decrease substantially with increasing soil depth, underscoring the fact that metals in contaminated soils are not all retained in topsoil of 0-15 cm. The study reported here provides data as information in the literature, since there is lack of previous findings on soil quality of this study area. The findings suggests the need for closer examination of speciation studies to quantify the proportion of the bioavailable phases of the metals.

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